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ETHNORELIGIOUS STUDY OF AL-QURAN AUDIOREMIDIATION IN REDUCING NANOPLASTICS IN SERAYU RIVER WATERS

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ABSTRAK

Sungai Serayu di Kabupaten Cilacap mengalami penurunan kualitas air akibat cemaran limbah, termasuk akumulasi nanoplastik. Nanoplastik merupakan partikel plastik berukuran sangat kecil yang sulit terurai dan berdampak negatif pada ekosistem perairan. Penelitian ini bertujuan mengkaji efektivitas audioremediasi berbasis etnoreligi dalam mereduksi nanoplastik pada air Sungai Serayu. Penelitian menggunakan design research. Pengumpulan data meliputi pengumpulan sampel air, filtrasi, dan perlakuan dengan audioremediasi menggunakan lantunan Al-Qur'an, musik rohani, dan musik keroncong. Dilanjutkan dengan sentrifugasi dan pengamatan ukuran partikel menggunakan mikroskop. Hasil penelitian membuktikan bahwa perlakuan dengan lantunan ayat suci Al-Qur'an memberikan hasil paling efektif, dengan rata-rata ukuran partikel menurun drastis hingga 362 nm pada waktu 1 jam dan menjadi 32,5 nm dalam waktu 24 jam. Citra gambar pada durasi 24 jam juga menunjukkan kebersihan sampel dari cemaran nanoplastik, dimana hanya tersisa sedikit partikel nanoplastik setelah perlakuan 24 jam. Hasil analisis Uji ANOVA menunjukkan bahwa musik keroncong dan musik rohani juga mampu mereduksi ukuran nanoplastik, namun penurunannya tidak secepat dan seefektif perlakuan dengan lantunan Al-Qur'an. Hasil analisis Uji BNT menunjukkan bahwa lantunan Al-Qur'an memiliki beda sangat nyata dengan air baku maupun air yang diberi perlakuan audioremediasi dengan musik keroncong dan lagu rohani. Dengan demikian lantunan Al-Qur'an efektif digunakan untuk mereduksi cemaran nanoplastik pada air.

Kata kunci: *Al-Quran, nanoplastik, Sungai Serayu, audioremediasi, etnoreligi*

ABSTRACT

The Serayu River has experienced a decline in water quality due to waste pollution, including the accumulation of nanoplastics. Nanoplastics are very small plastic particles that are difficult to decompose and have a negative impact on aquatic ecosystems. This study aims to examine the effectiveness of ethno-religion-based audio remediation in reducing nanoplastics in the Serayu River water. The study uses research design. Data collection involves water sampling, filtration, and treatment, accompanied by audioremediation using recitations from the Qur'an, spiritual music, and keroncong music. This was followed by centrifugation and particle size observation using a microscope. The results of the study prove that treatment with recitations from the Holy Qur'an was the most effective, with the average particle size decreasing dramatically to 362 nm within 1 hour and to 32.5 nm within 24 hours. The image at 24 hours also showed that the sample was free of nanoplastic contamination, with only a few nanoplastic particles remaining after 24 hours of treatment. The results of the ANOVA test *showed that keroncong music and spiritual music were also able to reduce the size of nanoplastics, but the reduction was not as fast or as effective as the treatment with recitations from the Qur'an. The results of the LSD test analysis showed that the recitation of the Qur'an had a very significant difference from raw water and water treated with audioremediation using keroncong music and spiritual songs. Thus, the recitation of the Qur'an is effective in reducing nanoplastic contamination in water.*

Keywords: *Al-Qur'an, nanoplastics, Serayu River, audioremediation, ethnoreligion*

INTRODUCTION

The Serayu River, a major waterway in Central Java that flows through Cilacap Regency, plays a crucial role in supporting the region's social, economic, and environmental systems (Sukarjo et al., 2023). It is essential for agriculture, fisheries, and hydroelectric power (PLTA), and provides livelihoods for local communities (Sari et al., 2025). In recent decades, however, the river's water quality has deteriorated significantly due to increased pollution from various sources, including solid and liquid waste and the accumulation of plastic debris (Lestari et al., 2023). Among these pollutants, nanoplastics warrant particular attention, as their presence often goes unnoticed.

Nanoplastics, defined as plastic particles between 20 and 255 nanometers in size, are increasingly recognized as emerging environmental pollutants with significant risks to ecosystems and human health (Wahl et al., 2021). These particles have been detected in substantial quantities in both bottled drinking water and river water, and are released during the washing and use of polyester textiles (Li et al., 2022). In Indonesia, the Serayu River, particularly the section flowing through Cilacap Regency, is beginning to experience the effects of nanoplastic pollution. Community activities along the river, including the disposal of domestic and industrial waste and the conversion of riverbanks into dumping sites, contribute to declining water quality. The accumulation of plastic particles and overall water pollution are further exacerbated by limited environmental awareness and inadequate waste management practices among riverside populations (Al Farizi, 2021).

Conventional remediation methods, such as filtration, absorption, and coagulation, have been implemented to address water pollution. However, these techniques are generally effective only for microparticles and are insufficient for removing nanoparticles (Schmaltz et al., 2020). Addressing this limitation requires alternative solutions that integrate technological innovation with local wisdom and cultural values. One promising approach is audioremediation, which utilizes sound waves to facilitate the reduction of nanoplastic particles. The application of sound waves generates pressure that simulates the physical stress found in river environments, thereby breaking down plastics to the nanoscale (Hwangbo et al., 2022).

Along the Serayu River, community life is inextricably linked to religious and cultural practices that have been passed down through generations. Various communal prayers, religious studies, and other religious rituals demonstrate their closeness to God (Rachmawati et al., 2021). The ethnoreligious approach in this study not only highlights the community's cultural and religious practices but also examines how sound waves from activities such as prayer and Quranic recitation can produce specific frequencies that scientifically have the potential to influence the structure or dynamics of particles in liquid media, including water contaminated with nanoplastics.

Several studies, such as those by Sarijan et al. (2021), have shown that nanoplastics have serious impacts on aquatic ecosystems and human health.

Meanwhile, Elgarahy et al. (2024) examined the effectiveness of ultrasonic waves in aggregating nanoplastic particles as a technical remediation method. However, these studies were limited to laboratory contexts and were mechanical in nature, and did not consider local social and cultural factors. To date, no research has been found that specifically examines the potential of sound waves in cultural and religious practices. Therefore, research on ethnoreligious audioremediation studies for nanoplastic reduction in the Serayu River waters of Cilacap Regency has a high degree of novelty.

METHOD

The study used a design research method. The study was conducted from May to June 2025. The research location was in Karangrena Village, Cilacap Regency. Sampling was carried out in the Serayu River, Cilacap Regency. Nanoplastic observations were conducted at the Pharmacy Laboratory of Universitas Al-Irsyad Cilacap (UNAIC). The primary data sources in this study were obtained through laboratory experiments in the form of nanoplastic observations before and after the audioremediation process with various types of sounds (Quran recitation, religious music, and keroncong music) and varying durations (1 hour, 2 hours, and 24 hours). Particle measurements were made using a microscope after the centrifugation process. Meanwhile, secondary data sources were obtained through literature studies related to nanoplastics, audioremediation, and ethnoreligious approaches from journals, books, and previous research reports. The tools and materials used in this study consisted of a microscope, a centrifuge, a microphone, a speaker, a dropper pipette, a test tube, a sample container, a sound frequency meter, and a filtering device in the form of filter paper, cotton, and a clean cloth. The raw materials were water samples from the Serayu River contaminated with nanoplastic particles.

The data collection method involved several stages: sampling the Serayu River water contaminated with nanoplastics, followed by a multi-stage filtration process to separate the microplastic particles from the nanoplastics. Audioremediation was then performed using three types of sound at a frequency of 50 Hz, set at 5 cm, for durations of 1 hour, 2 hours, and 24 hours. After treatment, the samples were sedimented by centrifugation to precipitate the nanoplastic particles and then observed under a microscope to detect their presence. Data analysis was conducted through descriptive retrospective analysis, comparing the average, smallest, and largest sizes of nanoplastic particles from each sound treatment and duration. The results were analysed to determine the effectiveness of each sound type in reducing nanoplastic size and to identify patterns of particle size reduction due to sound wave exposure based on the ethnoreligion of the Quran.

RESULTS AND DISCUSSION

The Serayu River, extending 180 km, is among the longest rivers on Java Island. During the Dutch East Indies colonial period (1830–1942), it functioned as a primary shipping and trade route in the Cilacap area (Erlangga & Andi, 2023). Over time, the Serayu River has experienced significant environmental challenges, particularly declining water capacity and quality (Arinda et al., 2023). Recent studies have examined suspended sediment transport, water quality monitoring, and pH distribution along the river basin (Fikriyya et al., 2024). Online monitoring systems and the STORET analysis method have been employed to assess water conditions, revealing pollution levels categorized as light to moderate (Arinda et al., 2023). The acidity (pH) in the Serayu watershed demonstrates a decreasing trend from upstream to downstream, with values ranging from 6.18 to 7.51 (Fikriyya et al., 2024). Research by Darwanto et al. (2025), indicates that the Serayu River contains substantial microplastic contamination, primarily due to indiscriminate waste disposal by residents. Despite this, the river remains a source of drinking water for Cilacap residents, managed by the Perusahaan Daerah Air Minum (PDAM) Tirta Wijaya. Monira et al. (2023) report that microplastic particles in the water continue to degrade into smaller particles, known as nanoplastics. S. Liu et al. (2024) and Yee et al. (2021) further note that nanoplastic particles possess a much greater toxic potential than microplastics, as they can penetrate organisms and the surrounding environment.

Nanoplastics are plastic particles ranging from 1 nm to 1 micrometre, formed through the degradation of larger plastics or produced intentionally for specific applications (Gigault et al., 2021). These particles exhibit diverse shapes, compositions, and morphologies, in contrast to the uniformity of synthetic nanoparticles (Pradel et al., 2023). Nanoplastics demonstrate high stability in aquatic environments, resist aggregation, and remain dispersed in water (Lai et al., 2022). Additionally, nanoplastics can adsorb heavy metals and organic pollutants, are readily transported by water currents, and can penetrate the cells of organisms. These properties may disrupt the growth, behavior, and reproduction of aquatic biota and pose toxic risks to human health (Atugoda et al., 2023).

Audioremediation is a concept that explores how audio media, such as audiobooks, podcasts, and radio, are transformed through technology and how this audio approach is used in cognitive, medical, and environmental interventions. In an environmental context, audioremediation refers to the use of sound waves or acoustic signals to reduce the number of particles, including fine particles or nanoplastics, in both air and water (Liu et al., 2022). Sound waves of a certain intensity can cause small particles to collide with each other and aggregate into larger particles, making them easier to settle or filter (Kilikevičienė et al., 2023). Furthermore, the combination of sound and electric fields can increase particle charge, accelerate the aggregation process, and improve particle reduction efficiency (Zhao et al., 2020).

Raw water samples were taken from the Serayu River, which had been polluted by plastic waste due to local community activities in Karangrena Village, Maos District, Cilacap Regency. The plastic waste carried by the river slowly decomposes naturally due to exposure to sunlight, water currents, and other physical and chemical processes. As a result, the plastic breaks down into small particles, known as microplastics and nanoplastics. The water samples were then filtered to remove large particles and microplastics. Filtration was carried out in stages using filters, filter paper, cotton, and clean cloth until the water was deemed to be completely free of microplastic particles (Figure 1).

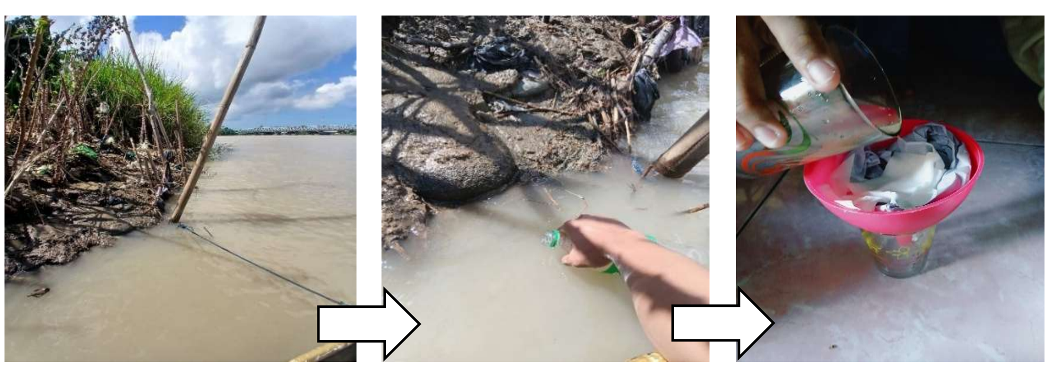

Figure 1. Serayu River Water Sampling

The audioremediation process was carried out by holding a clean, filtered water sample close to a microphone. The water sample container was then sealed in a soundproof container to allow the sound waves to penetrate the water without any external interference (Figure 2). In this process, the water sample was subjected to three different sounds: the recitation of verses from the Quran, Islamic hymns, and keroncong music. Each sound was subjected to the same treatment, with a frequency of 50 Hz and a microphone distance of approximately 5 cm from the water surface, allowing the sound to penetrate the water effectively. Each treatment was administered for three durations: 1 hour, 2 hours, and 24 hours, to assess the effect of prolonged sound exposure on the water's condition. After all treatments were completed, the water was carefully observed for any changes, including colour, clarity, and odour.

Figure 2. Audioremediation Process of Serayu River Water Samples

The audioremediation water sample was then pipetted into a test tube. The test tube was then placed into a centrifuge. The centrifugation process was carried out at a specific speed and time to allow the nanoplastic particles in the water to settle properly at the bottom of the tube (Figure 3). The nanoplastic sediment formed after this process was then further observed, both in terms of size, shape, and quantity, to determine the extent to which sound wave exposure during the audioremediation process affected the presence of these nanoplastic particles.

Figure 3. Nanoplastic Precipitation Process Using a Centrifuge

The centrifuged water samples were then observed under a microscope at up to 1,000x magnification. This stage involved observing and measuring the size of the nanoplastic particles within the water samples. Using a microscope, these tiny particles are much more clearly visible, making it easier to identify any size differences within the samples.

Figure 4. Results of observations of raw water samples

Figure 4 shows the results of observations using a microscope at 1000x magnification. Nanoplastic particles in raw water samples without any treatment were seen in large numbers, suspected to be nanoplastics, with fairly uniform sizes. The average visible particle size was approximately 899.5 nm, with the smallest being 814 nm and the largest being 985 nm. These results indicate that under initial conditions, raw water from the Serayu River, unexposed to sound or other treatments, tends to have large nanoplastic particle sizes.

(a). 1 hour treatment (b) 2 hours treatment (c). 3 hours treatment

Figure 5. Results of observations of water samples that were exposed to keroncong music

Table 1. Nanoplastic Size in Keroncong Music

No.	Treatment	Treatment Size (nm)		Average
		Minimum Size	Maximum Size	
1.	1 hour	791	814	802,5
2.	2 hours	544	621	582,5
3.	24 hours	432	600	516

Figure 5 and Table 1 show the results of observations using a microscope at 1,000x magnification. The size of nanoplastic particles in samples exposed to keroncong music appears to decrease with exposure time. In the 1-hour treatment, the smallest particle size was recorded at 791 nm, the largest at 814 nm, with an average of 802.5 nm. After 2 hours, the particle size decreased to a minimum of 544 nm, a maximum of 621 nm, and an average of 582.5 nm. This decrease in size was even more pronounced in the 24-hour treatment, with a smallest size of 432 nm, a largest of 600 nm, and an average of 516 nm.

(a). 1 hour treatment (b). 2 hours treatment (c). 3 hours treatment

Figure 6. Results of observations of water samples that were exposed to Islamic spiritual music

Table 2. The size of nanoplastics in the treatment of listening to Islamic religious music

No.	Treatment	Treatment Size (nm)		Average
		Minimum Size	Ukuran Terbesar	
1.	1 hour	500	670	585
2.	2 hours	500	650	575
3.	24 hours	400	570	485

Observations of samples treated with spiritual music are shown in Figure 6 and Table 2. After 1 hour, nanoplastic particle sizes ranged from 500 to 670 nm (average 585 nm). At 2 hours, the sizes slightly decreased (500–650 nm, average 575 nm). After 24 hours, sizes further declined to 400–570 nm, with an average of 485 nm.

(a). 1 hour treatment (b). 2 hours treatment (c). 3 hours treatment

Figure 7. Results of observations of water samples that were exposed to the recitation of the Qur'an

Table 3. Results of observations of water samples that were exposed to the recitation of the Qur'an

No.	Treatment	Treatment Size (nm)		Average
		Minimum Size	Ukuran Terbesar	
1.	1 hour	324	400	362
2.	2 hours	215	316	265,5
3.	24 hours	15	50	32,5

Figure 7 and Table 3 show the results of observations, the size of nanoplastic particles in samples exposed to the recitation of the holy verses of the Qur'an showed a very significant decrease with the length of exposure time. In the 1-hour treatment, the size of nanoplastic particles was observed to have the smallest size of 324 nm, the largest size of 400 nm, with an average of 362 nm. After 2 hours, the particle size decreased even further, with the smallest size of 215 nm, the largest size of 316 nm, and an average of 265.5 nm. The most drastic decrease in size was seen in the 24-hour treatment, where the particle size only ranged from 15 nm to 50 nm, with an average of 32.5 nm. This very significant decrease, especially at a duration of 24 hours, is strongly suspected to be influenced by the characteristics of the sound waves from the recitation of the Qur'an, which have a certain frequency, rhythm, and pattern so that they provide continuous acoustic pressure on the nanoplastic particles.

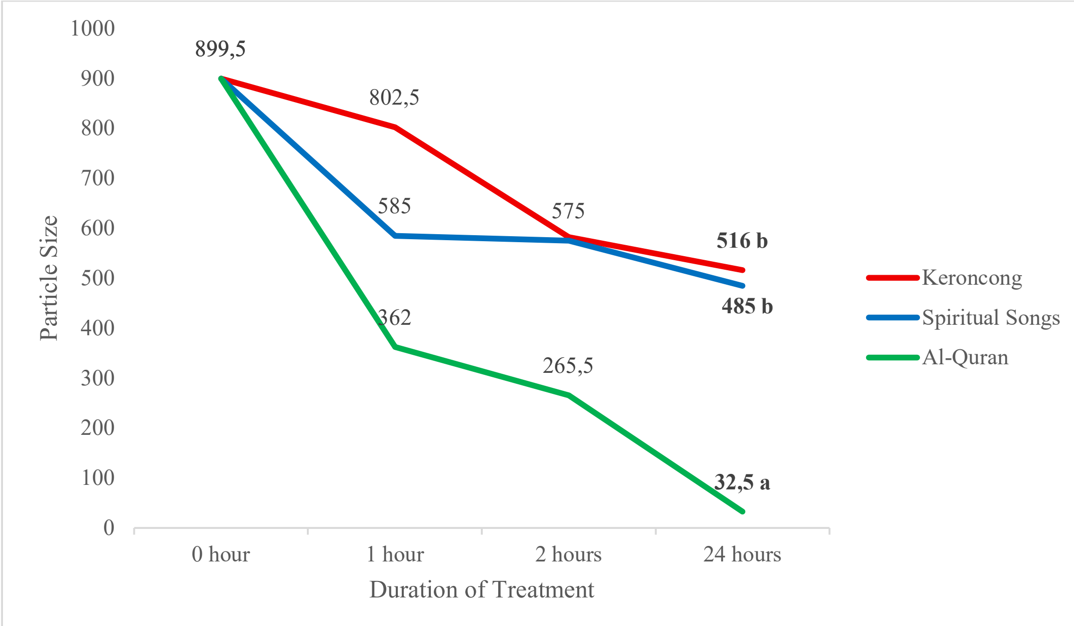

Figure 9. Audioremediation observation results

Based on the ANOVA analysis, a significance value of $\alpha < 0.05$ was obtained. This indicates an effect of the treatment on raw water containing nanoplastics. The LSD analysis showed differences in notation between the raw water and treated water, meaning all treatments differed significantly from the raw water. However, no significant difference was found between keroncong music and religious songs, while a significant difference occurred with the Quranic recitation treatment. Figure 7c displays the cleanest results from nanoplastic contamination. Therefore, Quranic recitation is the most effective at reducing nanoplastic particles in water.

Treating by reciting incantations, including prayers and Quranic verses, is an ethnoreligious practice still prevalent in Indonesia. The impact of Quranic recitation on average shows a significant effect. Similarly, ethnoreligious-based audioremediation significantly reduced the size of nanoplastic particles in water samples contaminated with nanoplastics in the Serayu River. Exposure to sound waves can create micro-acoustic pressure that triggers the fragmentation of nanoplastic particles into smaller sizes, even destroying them. This is clearly seen in all three treatments: keroncong music, religious music, and the recitation of the holy Quran, with varying degrees of effectiveness. The most significant size reduction was found in the treatment with the recitation of the holy Quran. The average particle size decreased drastically to 362 nm within 1 hour, and even to 32.5 nm within 24 hours. This strong effect is thought to be influenced by the frequency and harmony of the Quranic sound, which is more stable and rhythmic, thus producing a more effective resonance in breaking down nanoplastic particles. This study also shows that the longer the duration of exposure to sound waves, the greater the reduction in nanoplastic size that occurs. This proves that duration is an important factor in the effectiveness of audioremediation. Thus, the ethnoreligious approach based on sound waves not only has cultural value but also opens up opportunities as an ecological method to address nanoplastic pollution in waters.

CONCLUSION

This study proves that ethnoreligious-based audioremediation can reduce the size of nanoplastic particles in Serayu River water. Treatment with the recitation of the holy verses of the Qur'an gave the most effective results, with the average particle size decreasing drastically to 362 nm in 1 hour and to 32.5 nm in 24 hours. The images at a duration of 24 hours also showed the cleanliness of the sample from nanoplastic contamination, where only a few nanoplastic particles remained after 24 hours of treatment. The results of the ANOVA test analysis showed that keroncong music and religious music were also able to reduce the size of nanoplastics, but the reduction was not as fast and effective as treatment with the recitation of the Qur'an. The results of the BNT test analysis showed that the recitation of the Qur'an had a very significant difference with raw water and water treated with audioremediation with keroncong music and religious songs.

BIBLIOGRAPHY

Al Farizi, M. A. (2021). Perilaku Masyarakat Tepi Sungai dalam Masalah Sampah di Sekitar Sungai. In *https://osf.io/preprints/osf/6sa5v_v1*. OSF Preprints. https://doi.org/10.31219/osf.io/6sa5v

Arinda, E. S., Wahyono, H. D., & Santoso, A. D. (2023). Penentuan status mutu air Sungai Serayu menggunakan teknologi online monitoring (Onlimo) dengan metode analisa storet. *TRITON: Jurnal Manajemen Sumberdaya Perairan*, *19*(2), 102–113. https://doi.org/10.30598/TRITONvol19issue2page102-113

Atugoda, T., Piyumali, H., Wijesekara, H., Sonne, C., Lam, S. S., Mahatantila, K., & Vithanage, M. (2023). Nanoplastic occurrence, transformation and toxicity: a review. *Environmental Chemistry Letters*, *21*(1), 363–381. https://doi.org/10.1007/s10311-022-01479-w

Darwanto, A., Kurniatama, S. H., & Nugroho, S. A. (2025). Pemanfaatan Bonggol Pisang sebagai Biofilter Cemaran Mikroplastik di Perairan Kabupaten Cilacap. *Jurnal Inovasi Daerah*, *4*(1), 82–91.

Elgarahy, A. M., Eloffy, M. G., Priya, A. K., Yogeshwaran, V., Elwakeel, K. Z., Yang, Z., & Lopez-Maldonado, E. A. (2024). A review on the synergistic efficacy of sonication-assisted water treatment process with special attention given to microplastics. *Chemical Engineering Research and Design*, *206*, 524–552. https://doi.org/10.1016/j.cherd.2024.05.027

Erlangga, G., & Andi, A. (2023). Sungai Serayu dalam Tinjauan Sejarah Maritim: Peran dan Perkembangannya di Cilacap Pada Masa Hindia Belanda, 1830-1942. *Fajar Historia: Jurnal Ilmu Sejarah Dan Pendidikan*, *7*(1), 94–108. https://doi.org/10.29408/fhs.v7i1.12040

Fikriyya, N., Firmansyah, F. A., Susanti, S. T., & Hidayati, N. V. (2024). Sebaran Kadar pH di Daerah Aliran Sungai Serayu. *Maiyah*, *3*(3), 190–199. https://doi.org/10.20884/1.maiyah.2024.3.3.13205

Gigault, J., El Hadri, H., Nguyen, B., Grassl, B., Rowenczyk, L., Tufenkji, N., Feng, S., & Wiesner, M. (2021). Nanoplastics are neither microplastics nor engineered nanoparticles. *Nature Nanotechnology*, *16*(5), 501–507. https://doi.org/10.1038/s41565-021-00886-4

Hwangbo, S. A., Kim, I. Y., Kang, G., Kim, J., & Lee, T. G. (2022). Preparation of Environmentally Comparable Fragmented Polyethylene Nanoplastics for Toxicity Evaluation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4055966

Kilikevičienė, K., Chlebnikovas, A., Matijošius, J., & Kilikevičius, A. (2023). Investigation of the acoustic agglomeration on ultrafine particles chamber built into the exhaust system of an internal combustion engine from renewable fuel mixture and diesel. *Heliyon*, *9*(6), e16737. https://doi.org/10.1016/j.heliyon.2023.e16737

Lai, H., Liu, X., & Qu, M. (2022). Nanoplastics and Human Health: Hazard Identification and Biointerface. *Nanomaterials*, *12*(8), 1298. https://doi.org/10.3390/nano12081298

Lestari, S. D., Wardhono, N. A. S., Fikriyya, N., Ulinuha, M. R., & Hidayati, N. V. (2023). Determinasi Status Mutu Air Daerah Aliran Sungai (DAS) Serayu Menuju Pengelolaan DAS Berkelanjutan. *Jurnal Perikanan Unram*, *13*(4), 941–950.

Li, Y., Wang, Z., & Guan, B. (2022). Separation and identification of nanoplastics in tap water. *Environmental Research*, *204*, 112134. https://doi.org/10.1016/j.envres.2021.112134

Liu, S., Chen, Q., Ding, H., Song, Y., Pan, Q., Deng, H., & Zeng, E. Y. (2024). Differences of microplastics and nanoplastics in urban waters: Environmental behaviors, hazards, and removal. *Water Research*, *260*, 121895. https://doi.org/10.1016/j.watres.2024.121895

Liu, Y., Pan, C., Zhang, L., Ding, H., Huang, H., Xu, F., Bu, S., Jin, H., & Xu, W. (2022). Experimental and numerical study on the acoustic coagulation of charged particles. *Powder Technology*, *410*, 117780. https://doi.org/10.1016/j.powtec.2022.117780

Monira, S., Roychand, R., Bhuiyan, M. A., & Pramanik, B. K. (2023). Role of water shear force for microplastics fragmentation into nanoplastics. *Environmental Research*, *237*(Part 1), 116916. https://doi.org/10.1016/j.envres.2023.116916

Pradel, A., Catrouillet, C., & Gigault, J. (2023). The environmental fate of nanoplastics: What we know and what we need to know about aggregation. *NanoImpact*, *29*, 100453. https://doi.org/10.1016/j.impact.2023.100453

Rachmawati, N., Alhassan, M. L., & Syafii, M. (2021). Sedekah Bumi : Model Kebersyukuran dan Resiliensi Komunitas pada Masyarakat Pesisir Utara Jawa Tengah. *Jurnal Penelitian*, *15*(1), 1–26. https://doi.org/10.21043/jp.v15i1.9075

Sari, L. K., Cahyo, T. N., Kamaluddin, R., Setyowati, E. A., & Khotimah, A. H. (2025). Sustainable Management by Forest Farmer Group in Serayu Watershed. *Technium Sustainability*, *9*, 1–15. https://doi.org/10.47577/sustainability.v9i.12417

Sarijan, S., Azman, S., Said, M. I. M., & Jamal, M. H. (2021). Microplastics in freshwater ecosystems: a recent review of occurrence, analysis, potential impacts, and research needs. *Environmental Science and Pollution Research* , *28*, 1341–1356.

Schmaltz, E., Melvin, E. C., Diana, Z., Gunady, E. F., Rittschof, D., Somarelli, J. A., Virdin, J., & Dunphy-Daly, M. M. (2020). Plastic pollution solutions: emerging technologies to prevent and collect marine plastic pollution. *Environment International*, *144*, 106067. https://doi.org/10.1016/j.envint.2020.106067

Sukarjo, S., Handayani, C. O., Rahayu, S. H., & Hidayat, S. (2023). Assessment of Contamination Level and Source Apportionment of Heavy Metals in Serayu River Water. *International Journal of Conservation Science*, *14*(4), 1641–1658. https://doi.org/10.36868/IJCS.2023.04.26

Wahl, A., Juge, C. Le, Davranche, M., El Hadri, H., Grassl, B., Reynaud, S., & Gigault, J. (2021). Nanoplastic occurrence in a soil amended with plastic debris. *Chemosphere*, *262*, 127784. https://doi.org/10.1016/j.chemosphere.2020.127784

Yee, M. S.-L., Hii, L.-W., Looi, C. K., Lim, W.-M., Wong, S.-F., Kok, Y.-Y., Tan, B.-K., Wong, C.-Y., & Leong, C.-O. (2021). Impact of Microplastics and Nanoplastics on Human Health. *Nanomaterials*, *11*(2), 496.

https://doi.org/10.3390/nano11020496

Zhao, Y., Zhou, H., Tian, Z., Zeng, X., & Gong, C. (2020). Numerical simulation of acoustic agglomeration of fine particles in sintered flue gas of steel production. *IOP Conference Series: Earth and Environmental Science*, *508*(1), 012003. https://doi.org/10.1088/1755-1315/508/1/012003